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ABSTRACT

This seventh in a series of seven modules for a course titled Nondestructive Examination (NDE) Techniques I describes radiographic specifications and code requirements. The module follows a typical format that includes the following sections: (1) introduction, (2) module prerequisites, (3) objectives, (4) notes to instructor/student, (5) subject matter, (6) materials needed, (7) procedures, (8) data table, (9) reference materials, (10) test. (The course is one of fifteen technical courses for the second year of a two-year postsecondary curriculum in Nuclear Quality Assurance/Quality Control Technology.) (LRA)

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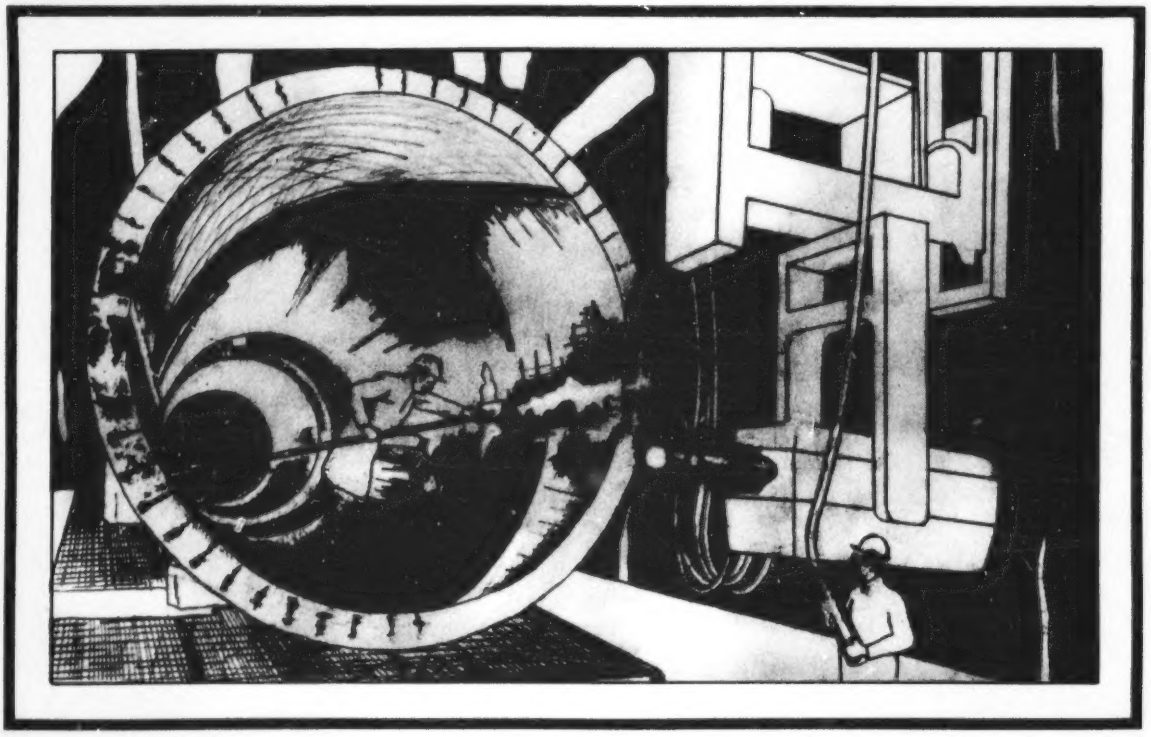
# NUCLEAR TECHNOLOGY

## COURSE 26 NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES I

### MODULE 26-7 Radiographic Specifications and Code Requirements



CE 024 252

GENERAL PHYSICS CORPORATION
Columbia , Maryland

# COURSE MODULES

COURSE 26 NONDESTRUCTIVE EXAMINATION (NDE) TECHNIQUES I

| | |
|---|---|
| Module 26-1 | Visual Tests |
| Module 26-2 | Leak Tests |
| Module 26-3 | Hydrostatic Tests |
| Module 26-4 | Liquid Penetrant Tests |
| Module 26-5 | Fundamentals of Radiography |
| Module 26-6 | Radiography Inspection |
| Module 26-7 | Radiographic Specifications and Code Requirements |

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This module was prepared for General Physics Corporation by Rick Pelton and John Espy, General Physics Corporation.

GENERAL PHYSICS CORPORATION

1979

# INTRODUCTION

Radiography is used to detect features of a component or assembly that exhibit a difference in thickness or density as compared to surrounding material, and to provide a photographic record of the inspection technique and results.

An acceptable radiograph is one which has a representative image of the specimen, has a fully distinguishable penetrameter image, exhibits suitable radiographic arrangement and techniques, and exhibits precision and uniformity of film processing. Modules 25-5 and 25-6 cover these characteristics, and are prerequisite to this module.

The finished radiograph becomes a valuable document only when evaluated by a qualified film interpreter. The film interpreter must examine the radiograph on an appropriate illuminator or film viewer, determine the acceptability of the radiograph procedure, analyze the nature and extent of any abnormal conditions or discontinuities observed in the specimen image, evaluate the findings of the examination by comparison to standards or specifications, and report the inspection results accurately.

The nondestructive testing inspector who normally performs film reading and interpretation must possess certain personal qualifications. These requirements are included in personnel standards published by the American Society for Nondestructive Testing, government agencies and many private manufacturers. Usually, a minimum level of visual acuity, minimum standards of education and training, and demonstrated proficiency are required of all interpreters of radiographs.

The QA/QC technician may not be required or qualified to perform the reading and interpretation of radiographs, but he should be familiar with all aspects of the activity and the applicable codes and specifications. The QA/QC technician frequently monitors film reading and interpreta-

tion, verfies conformance to code requirements and specifications, reviews test reports, and audits film interpreters and their work.

## MODULE PREREQUISITES

The student/trainee must have completed modules 26-5 and 26-6.

## OBJECTIVES

To satisfactorily complete this module, the trainee shall:

1. Demonstrate a knowledge of radiographic specification, code requirements and fundamentals of film interpretation by responding correctly to written exercises, which are similar to the questions included in the American Society for Nondestructive Testing SNT-TC-IA Level II certification written test.
2. Demonstrate a knowledge of discontinuities in materials by responding correctly to written questions about welds, castings and other commonly radiographed materials.
3. Demonstrate a knowledge of ASME and ASTM radiographic specifications and code requirements by completing exercises comparing specimen sketches and descriptions

to the standards illustrated and/or described in this text, and determining the acceptability of each specimen.

4. Demonstrate a knowledge of radiographic film interpretation and evaluation techniques by responding to related written questions.

## DISCONTINUITIES IN MATERIALS

In addition to an understanding of the principles of radiography, the successful interpretation of radiographs requires a knowledge of the materials being tested so that the images of discontinuities observed may be related to the serviceability of the specimen.

The term discontinuity refers generally to any kind of flow, defect, fault or lack of continuity in a material that is required to be continuous throughout a given volume. Some general types of discontinuities are summarized:

- Cracks and Breaks - A "crack" is a defect in which the discontinuity has a relatively large cross-section in one direction and a small or negligible cross-section when viewed in a direction perpendicular to the first. A "break" is a crack of such a size or location that it may cause the object to separate into two parts.

  Cracks assume a variety of forms. They may have branches, parallel cracks and changes of direction. In general the cause of a crack is a stress perpendicular to the plane of the crack. Stresses may be caused by heating, cooling, cold working and deforming of metal. "Hot tears" may occur in castings when the mold interferes with free contraction of the casting.

  "Crazy pattern" can be produced when the surface of a piece of metal is made very hot in a relatively small area. Grinding, some types of welding operations, and some flame-hardening processes may cause this kind of crack.

- Holes - Gas holes, cavities, holes or air locks are internal defects or voids where it is expected to find solid material. Many such discontinuities cannot be seen from the surface and radiography or other nondestructive testing methods must be used to detect them.

  "Porosity" is a discontinuity in the form of a collection of small holes or voids in a material.
- Lack of Fusion - In the welding of materials, the failure of the weld metal to fuse properly with the base metal is termed "lack of fusion". In castings, lack of fusion occurs where two independent streams of molten metal meet or where a stream splits and meets again with a slightly lower temperature, too low to allow the two streams to fuse together. This phenomenon is also referred to as a "cold shut".

  In the casting process, chaplets are pieces of metal used to position cores in molds. When the molten metal is introduced in the mold, the chaplets are supposed to fuse and become a part of the casting. In practice, they seldom fuse completely, and are referred to as "unfused chaplets" when this condition occurs.
- Inclusions - Inclusions are foreign materials, metallic or non-metallic, which are entrapped in cast material or weld metal. In castings, inclusions may consist of slag, sand or parts of the mold surface that come off in the molten metal. Weld metal may include materials such as slag, silvers of tungsten electrodes, or particles resulting from improper cleaning between passages.

- Surface Irregularities - Surface irregularities are conditions such as surface pits, formed by escaping gas bubbles, excess weld metal, or weld "undercut" which is a reduction in base metal thickness at the point where the last weld pass fused to the surface.

  Surface irregularities may or may not be a defect that renders the material unserviceable. The surfaces of parts to be radiographed should first be visually examined to identify any surface irregularities so that they and internal discontinuities may be distinguished on the radiograph.

## RADIOGRAPHS OF WELDS

One of the largest uses of industrial radiography is for examining welds. Defects in welds usually consist of either a void in the weld metal or an inclusion in the surrounding weld metal. The more common weld defects are described below, along with their cause and effect, and appearance on the radiograph:

- Gas Holes and Porosity - Gas may be formed in fusion welding because of poor control of arc current, technique used, electrodes used, and quality of base metal. The term "porosity" is used to describe gas inclusion that occur as spherical cavities in the weld metal. Gas inclusions may also occur as a tube-like cavity sometimes referred to as a "wormhole". Porosity may occur as single cavities, in clusters of cavities, or randomly scattered cavities. Linear porosity may also occur along with incomplete penetration and is a series of

cavities distributed along a line that runs lengthwise with the weld.

- Weld Slag Inclusions - Slags are usually oxides produced by arc welding. They serve to help take impurities from the molten metal and to form an insulating layer over the weld to control cooling rates. Some slag may be trapped in the weld metal if it fails to remain molten long enough for the slag to rise to the surface. In welding requiring multiple passes, slag may be left on previous passes unless properly cleaned. Slag inclusions may be located along the edges of the weld metal deposits and run in a line along the length of the weld.

  Since the oxides making up slags are usually of a lower density than iron, they show up as dark, irregular shapes on radiographs. Slag inclusions can occur singly, in clusters, or scattered randomly throughout a weld. They may also occur in a linear distribution. The images may have sharp, pointed ends and may be of variable density.

  Slag lines appear along the edge of a weld as an irregular or continuous dark line on the radiograph. These are usually caused by insufficient cleaning between weld passes. Voids left between passes by irregular deposits of metal cause lines that have a similar radiographic appearance.

- Cracks or Breaks - Cracks in welds are usually produced by internal stresses caused by shrinkage of the cooling weld. Cracks may be along the weld seam or they may be across the weld seam. Cracks are generally wavy or zig-zag lines and may have fine hairline cracks branching off from the main crack.

The radiographic image of a crack defect is a narrow line that is usually irregular. If the plane is not exactly in line with the radiation beam, a faint, dark linear shadow may result. In this case, additional radiographs should be taken at other angles.

- Lack of Penetration - Lack of penetration is the failure of the root pass to fuse properly with the base metal at the root, and occurs at the root opening at the bottom of the welding groove or at the center of the weld for two-sided welding. Root openings are used to permit peentration of fusion to the bottom of the weld opening or groove. Often tack welds are used to prevent movement of pieces being welded, followed by one or more passes made with the beads being laid over each other until the groove is filled.

  If the root opening is too small for the weld rod and the current being used, incomplete penetration may result. Sometimes poor beveling or preparation of the weld groove can cause voids at the root area of the weld. Where possible, a cover pass on the back side of the weld may fill such a void.

  The radiographic image of such a void appears as a straight, dark line in the center of the weld. The width may vary from a thin, sharp line to a broad, diffused line. Slag inclusions and gas holes may be found in the connection with a lack of penetration void. These may cause enlargement of the primary dark line, or cause it to be accompanied by a sort of dotted line. Slag inclusions may cause the primary line to appear broad and irregular.

Sometimes, lack of penetration may show on a radiograph as a very narrow dark line. The narrowness may be due to a drawing together of the plates being welded and the lack of penetration may be very severe.

- Lack of Fusion - Lack of fusion occurs as a result of lack of heat or poor cleaning of the fusion face of a weld bevel. The weld metal may not fuse to the parent metal, and remains separated by a thin layer of oxide, resulting in a discontinuity along the wall of the bevel.

  A radiograph of a lack of fusion shows a very thin, straight, dark line parallel to and on one side of the weld image. A lack of fusion line is usually straight on one side and irregular on the other.

- Tungsten Inclusions - Tungsten particles or splinters may be generated by the contact of the tungsten electrode used in arc welding, and become trapped in the metal that is deposited. No fusion of the tungsten will occur due to its high melting point. Tungsten is a dense, high atomic weight material with higher radiation absorption than iron, appearing as light marks on a radiograph.

  Tungsten inclusions may appear as single light spots, or as clusters of small light spots, and usually are irregular in shape.

- External Discontinuities - Various kinds of surface irregularities may cause density variations on a radiograph.

  A common surface discontinuity is undercutting, which is caused by melting of the upper edge of the beveled weld face. When insufficient weld metal

is deposited to fill the groove, the base metal may be reduced in thickness at the point of fusion on the edge of the weld bead, resulting in the formation of a radiographic image which shows a dark line of varying width and density. The darkness or density of the line indicates the depth of the undercut.

In the multipass welds on horizontal positions, a rough top surface frequently results with longitudinal grooves paralleling the weld seam. On the radiograph, these grooves appear as dark lines with diffused edges, and should not be mistaken for slag lines which are narrow and sharply defined. These dark lines are seldom straight, but are parallel to the weld seam.

Molten metal sometimes flows through the root of the weld groove and forms hanging drops of metal, or "grapes", on the backside of the weld. This condition shows a round, light spots on the radiograph.

In overhead welding, a concavity at the root of the weld may be formed. This condition means less weld metal at the root, and will show on the radiograph as a dark, broad line at the center of the weld without sharply defined boundaries.

Weld grooves not completely filled with weld metal appear as dark lines on the radiograph. If the lack of fill occurs at the bevel, the dark line will be located on one edge of the weld image and will have a sharp border on one side and an irregular border on the other side. If the incomplete fill occurs in the center of the weld, the dark line will be rather wide and have diffused borders.

Weld grooves may be overfilled due to an excessive number of passes or an inadequate arc current. The overfill is referred to as "weld reinforcement". If the reinforcement is too high, the weld radiograph will show a lighter line down the weld seam. There will be a sharp change in image density where the reinforcement meets the base metal.

Weld excess metal is deposited on the final pass, the excess metal may overlap the base metal with a lack of fusion at the edge. A sharp change in image density between reinforcement and base metal will show in the radiograph, with an irregular edge image of the reinforcement.

Reinforcement thickness may be reduced on a cover pass at the end of a bead laid with an electrode which is to be changed. Increased thickness may occur at the point where the new electrode is started. The extra reinforcement forms a crescent shape with its convex side nearest the reduced reinforcement area left by the first electrode. The radiograph shows a crescent shaped image of less density because of extra metal.

In pipe welding, it is often impossible to make a cover pass at the root of the weld. A backing ring is frequently inserted before welding and left inside the pipe. This ring is partially fused to the weld metal on the root pass, and produces a well-defined image on the radiograph as a light band. The weld reinforcement shows up as a still lighter line across this band. Many of the usual weld discontinuities may still occur where backing rings are used. Slag entrapment may cause concavity at the

root during the root pass, and lack of penetration also may occur.

## RADIOGRAPHS OF CASTINGS

Another major use of industrial radiography is for examining ferrous and nonferrous castings. A casting is a piece of metal formed in a mold which is a shaped cavity prepared to receive molten metal. Molds of many types and shapes are used to cast such parts as pump casings and impellers, valve bodies and parts, motor housings and frames, pipe, and pipe fittings.

Radiography serves the foundry or casting industry in two ways: (1) it is used to inspect casting to control quality of production, or to avoid service failures, and (2) it is used as an aid in casting design in the development of good foundry techniques related to chilling, gating systems, risering and venting.

The thoroughness with which a casting should be radiographed depends upon the design and use to which the casting will be put. Castings that must undergo high stresses and which may not have a high safety factor may require extensive radiographing. Castings not subjected to high stresses may require only a minimum of radiography necessary to detect the most severe defects.

Finished casting products, such as pumps, valves and pipe fittings are frequently radiographed during installation to verify their integrity and freedom from unacceptable discontinuities. Similar radiographic examinations may be performed during preventive maintenance, repair, or inservice inspection operations.

Some of the commonly found discontinuities in castings which appear on radiographs are listed below:

- Gas Holes - The entrapment of gas as molten metal cools and solidifies in a mold produces voids known as "gas holes." The gas may have been dissolved in the metal, it may arise from the mold, or it may have been trapped as the molten metal was "gated" into the mold. The holes may occur singly, in clusters, or randomly distributed throughout the casting. Gas holes appear on the radiograph as dark areas with smooth borders.

  In evaluating the effects of gas holes found by radiography, the end use of the casting should be considered. The part may be required to hold liquid or gas, as would a valve body or pump casing, or it may be highly stressed, as a motor frame. The effects of gas holes on its function, therefore, should be studied. The service requirements for the part should be known and used in the interpretation of radiographs showing defects or discontinuities such as gas holes.

  Generally, gas holes weaken a part. The amount of weakening is based on the size of the gas hole or holes in relation to the cross-section of the part in which they exist. Gas holes grouped closely may be considered as one larger hole. Gas holes may be aligned in such a way as to represent a "propagating" discontinuity. This is a serious defect which renders the part unacceptable, particularly if the part is subjected to repeated vibration or shock stresses.

- Porosity - A spongy or porous condition in a casting is known as "porosity". Two types of porosity have been identified: gas porosity and shrinkage porosity.

Gas porosity is caused by the release of gas from the cooling metal and from green sand molds. The inclusion of various kinds of impurities as well as high temperatures may also account for gas in a casting. Gas porosity appears as very small, round, dark spots on a radiograph, and may vary from very minute spots closely bunched to single large round spots.

Shrinkage porosity may occur as a result of improper cooling and shrinkage. If the risers cool and solidify prematurely, molten metal is not available to keep the mold cavity completely filled as the cooling process continues. Some or all of the casting then may have some shrink porosity, which appears as a dark, highly irregular-shaped image on the radiograph, easily distinguishable from gas porosity.

- Shrinkage Cavities - Shrinkage cavities are voids caused by an insufficient amount of molten metal in the mold when the casting cools, and are usually found along with shrink porosity. Early setting of the metal in the risers may cause a part of the casting to receive insufficient metal as the part sets. Shrinkage cavities appear on a radiograph as dark irregular-shaped spots which vary considerably in cross-sectional area depending upon the size of the casting.

Shrinkage cavities and gas holes have a similar effect on the serviceability of castings. Shrinkage cavities are considered to be serious defects, as they are propagating types of discontinuities.

- Microshrink - A from of shrinkage encountered mostly in non-ferrous castings such as aluminum alloy or

especially magnesium. It occurs usually at discontinuities of section such as the intersection of a thin web with a heavy boss, rib or flange. It is more severe if the fillet radius is less than the thickness of the thinner element (web etc.) This shrinkage results usually from differential rates of cooling in the thin and heavy sections. It is usually of extremely small voids or grain separations, showing a faint but discernible irregular shadow on the film. It may occur as a shrink-strain (residual stress) only, which cannot be detected by x-rays, but only by destructive strength or impact testing. Unless there is evidence of ample gates or risers in such thin elements or documentation of proper stress relief, great care should be used in both x-ray and physical testing of such castings to rule out potentially unsafe microshrink and residual stress. The level of care required is of course related to the probability and consequences of failure in a particular casting.

- Inclusions - Foreign materials, such as sand, slag or oxide, entrapped in a casting are known as inclusions. Inclusions may or may not affect the serviceability of the casting, depending on the quantity and location within the casting. Inclusions may appear either as dark spots or light spots on the radiograph, depending upon the relative densities of the inclusion and the base metal.
- Misruns - A misrun is the term applied to a casting containing a void produced when molten metal failed to fill the mold completely. It may be a minor void which is externally apparent, or it may connect to a deeper cavity which is not apparent on the surface, but is visible on the radiograph. Misruns appear on radiographs as dark areas with well-defined borders.

- Cold Shuts - The unfused-condition that may result in a casting when two separate streams of molten metal fail to fuse together upon meeting is called a cold shut. This condition occurs with premature cooling and setting of the molten metal. Cold shuts appear as well-defined dark lines on a radiograph, but may be difficult to detect.
- Cracks - Cracks may be caused by stresses in cooling of the casting, incorrect design of the casting, or by rough handling of the mold. In most cases, a crack makes a casting unacceptable. On a radiograph, cracks appear as dark irregular, intermittent or continuous lines. Cracks are usually very irregular and may not align properly with the radiation beam to produce a distinct image. Exposures from several different locations may be necessary, therefore, to determine the extent of a crack or to even accurately locate one.
- Segregation - The constituent metals in certain alloys used for castings sometimes tend to separate in spots during cooling in the mold producing segregation. This condition will show on the radiograph as light and dark blotches.
- Surface Irregularities - The most common surface irregularities are surface pits and excess metal. The surfaces of a part should be studied carefully so that the interpreter can distinguish any irregularities from internal discontinuities.

  Surface pits usually appear on the radiograph as diffused dark spots with poorly defined borders, similar to the images of inclusions.

  Excess metal appears as light areas corresponding to the dimension of the excess metal.

## RADIOGRAPHIC STANDARDS

In this section on standards, the following abbreviations will be used:

- ASME - American Society of Mechanical Engineers Boiler and Pressure Code
- ASTM - American Society of Testing and Materials Standards
- USAS - USA Standard Codes (Published by ASME)

Industrial radiography is generally performed in accordance with specific radiographic codes and standards or manufacturer's specifications. The radiographer and the interpreter must be familiar with the applicable standards so that the required radiographic quality is attained, and that the proper judgement is made as to the acceptability of the material examined.

Most U.S. codes and specifications for radiographic inspection require that the sensitivity to a specific flaw size be indicated on each radiograph. Sensitivity is determined by placing a penetrameter (image - quality indicator) that is made of substantially the same material as the specimen directly on the specimen prior to each exposure. Usually, the penetrameters are placed on the side of the specimen nearest the source. Penetrameter thickness is usually specified to be 2% of the specimen thickness, although 1% and 4% penetrameter thickness also are common. ASTM and ASME plaque - type penetrameters are most commonly used types, and are discussed in greater detail in Module 26-5.

A typical standard for radiographic examination methods is setforth in ASME Code, Section V, Article 2, "Radiographic Examination". This standard defines such requirements as

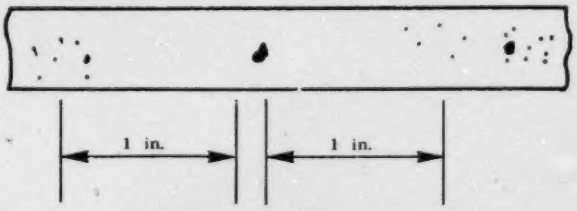
surface preparation, film selection, screens and processing, radiographic quality, radiographic density, scattered radiation control, material/film identification, radiation sources, radiographic image sharpness, selection and placement of penetrameters, procedure compliance, and evaluation of radiographs.

Other sections of the ASME Code provide specific acceptance criteria for applicable equipment and piping covered by the Code. As an example, the ASME Code, Section 1, Appendix A-250, provides Acceptance Standards for Radiographically Determined Porosity in Welds, as applicable to the fabrication of power boilers. This part of the Code defines relevent indications, aligned rounded indications, and spacing, and has charts of typical indications (discontinuities) illustrating maximum acceptable assorted, randomly dispersed, and clustered rounded indications for different weld thickness greater than 1/8 inch. These charts are known as porosity charts and are illustrated in Figure 26-7-1 through 26-7-6 , which were extracted from the Code. Other sections of the ASME Code, applicable to nuclear power plant components and to pressure vessels have similar radiographic examination acceptance standards and charts.

Another type of acceptance standard is the comparison or reference radiograph. Comparison radiographs have been prepared by the ASTM along with other reference materials for controlling quality in radiographic testing and for providing standard acceptance criteria for steel castings, aluminum and magnesium castings, and steel welds. For example, the materials prepared for steel castings include sets of radiographic negatives of defects encountered in carbon-steel and alloy-steel castings. They are intended to help in the classification of defects revealed by radiographic inspection. A set of plates is available for x-ray radiographic inspection, and another for gamma-ray and million-volt x-ray radiographic inspection.

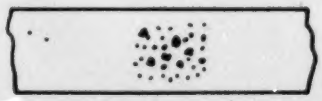
RANDON ROUNDED INDICATIONS

Typical concentration and size permitted in any 6 in. length of weld.




ISOLATED INDICATION

Maximum size per Table 1

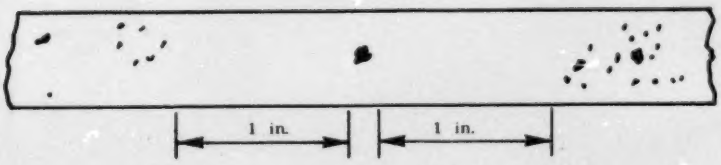


CLUSTER

Figure 26-7-1 ASME Porosity Chart
Chart for 1/8 In. to 1/4 In., Inclusive

RANDOM ROUNDED INDICATIONS

Typical concentrationand size permitted in any 6 in. length of weld.




ISOLATED INDICATION

Maximum size per Table 1

CLUSTER

Figure 26-7-2 ASME Porosity Chart
Chart for Over 1/4 In. to 3/8 In., Inclusive

RANDOM ROUNDED INDICATIONS

Typical concentration and size permitted in any 6 in. length of weld.

CLUSTER

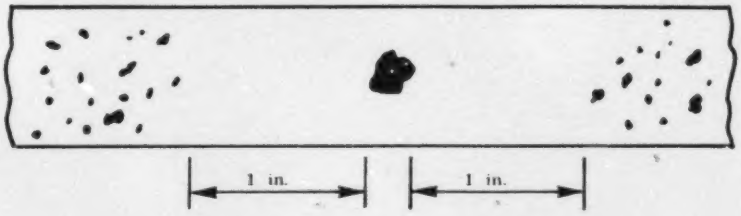
ISOLATED INDICATION

Maximum size per Table 1

Figure 26-7-3 ASME Porosity Chart
Chart for Over 3/8 In. to 3/4 In., Inclusive

RANDOM ROUNDED INDICATIONS

Typical concentration and size permitted in any 6 in. length of weld.

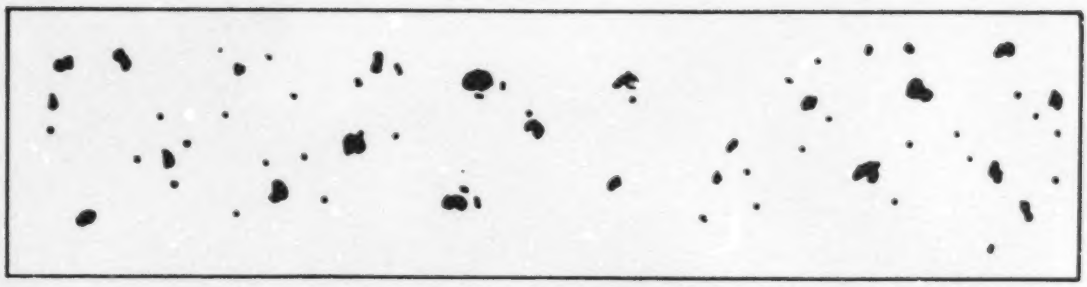



ISOLATED INDICATION

Maximum size per Table 1

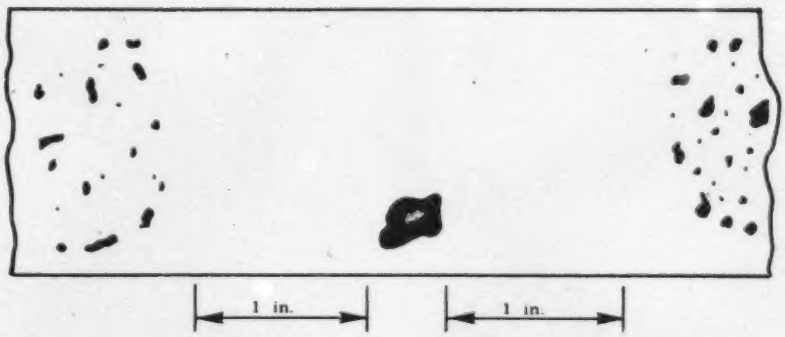
CLUSTER

Figure 26-7-4 ASME Porosity Chart
Chart For Over 3/4 In. to 2 In., Inclusive



RANDOM ROUNDNESS INDICATIONS

Typical concentration of size permitted in any 6 in. length of weld.




ISOLATED INDICATION

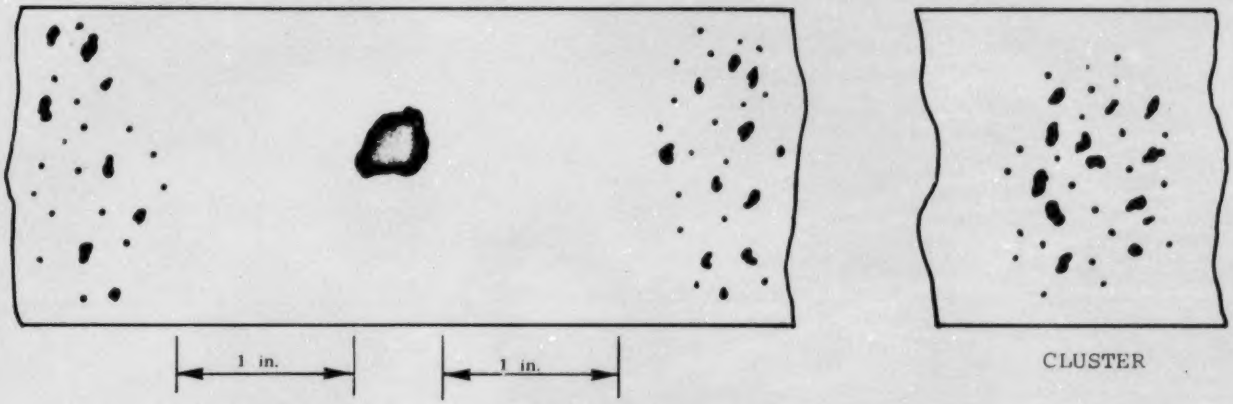
Maximum size per Table 1

CLUSTER

Figure 26-7-5 ASME Porosity Chart
Chart For Over 2 In. To 4 In., Inclusive

RANDOM ROUNDNESS INDICATIONS

Typical concentration and size permitted in any 6 in. length of weld.




ISOLATED INDICATION

Maximum size per Table 1

Figure 26-7-6 ASME Porosity Chart
Chart for Over 4 In.

TABLE 1
(Examples Only)

| Thickness t, in. | Maximum Size of Acceptable Rounded Indication, in. | | Maximum Size of Nonrevelant Indication, in. |
|---|---|---|---|
| | Random | Isolated | |
| Less than 1/8 | 1/4t | 1/3t | 1/10t |
| 1/8 | 0.031 | 0.042 | 0.015 |
| 3/16 | 0.047 | 0.063 | 0.015 |
| 1/4 | 0.063 | 0.083 | 0.015 |
| 5/16 | 0.078 | 0.104 | 0.031 |
| 3/8 | 0.091 | 0.125 | 0.031 |
| 7/16 | 0.109 | 0.146 | 0.031 |
| 1/2 | 0.125 | 0.168 | 0.031 |
| 9/16 | 0.142 | 0.188 | 0.031 |
| 5/8 | 0.156 | 0.210 | 0.031 |
| 11/16 | 0.156 | 0.230 | 0.031 |
| 3/4 to 2 incl. | 0.156 | 0.250 | 0.031 |
| Over 2 | 0.156 | 0.375 | 0.063 |

ASME Porosity Criteria

Much of the pressure piping in nuclear power plants which are now in operation was fabricated and tested in accordance with USAS Code for Pressure Piping, B31.7, "Nuclear Power Piping". Appendix B of the standard specifies the requirements for nondestructive examinations, and includes the following acceptance standards for weld radiography:

- USAS B31.7, Paragraph B-1-140 Acceptance Standards - Unacceptable welds, unless the defects are removed and the weld repaired, are those sections of welds that are shown by radiography to have:

1. any type of crack or zone of incomplete fusion or penetration;
2. any elongated inclusion, such as slag or tungsten, that has a length greater than 1/4 inch for t up to 3/4 inch inclusive, 1/3 t for over 3/4 inch to 2-1/4 inch inclusive, and 3/4 inch for t over 2-1/4 inch;
3. any group of inclusions in line that have an aggregated length greater than t in a length of 12 t except when the distance between the successive imperfections exceeds 6 L, where L is the length of the longest imperfection in the group; and
4. porposity in excess of that shown as acceptable by the porosity standards given in Appendix IV in Section III of the ASME Boiler and Pressure Vessel Code.

The American Petroleum Institute (API) publishes standards for pipeline fabrication and welding. The API standards include sketches and measurements to describe the severity and acceptability of defects in welds. Figure 26-7-7, API Acceptance Standard for Porosity in Pipeline Welds, is typical of the standards and sketches produced by that organization.

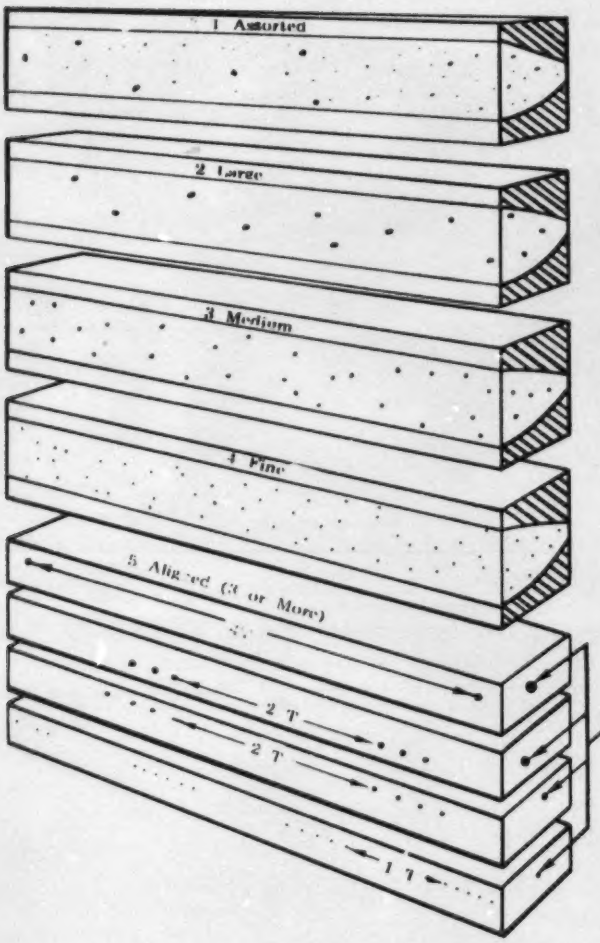



Figure 26-7-7 A.P.I. Acceptance Standard for Porosity in Pipeline Welds

Many other standards are also used for radiographic examination work, including military standards and standards developed by manufacturers. It is important that all applicable procedure standards be available to the radiographer before he proceeds with an inspection, and that appropriate acceptance standards have been established and are available for reference.

## EVALUATION OF RADIOGRAPHS

A discontinuity detected by radiography is meaningless unless compared to a known conditioner standard, and evaluated for acceptance or rejection. Acceptance standards define the radiographic appearance of least acceptable conditions. Specimen evaluation, then, consists of comparing the interpreted image on the film with the least acceptable condition in terms of the type, quantity and severity level of the discontinuities that are found, and making a judgement to accept or reject the specimen.

The main characteristics of a discontinuity, e.g., type, specific shape, size, orientation and location, determine its overall effect on a part. Type and location govern relative importance; specific shape influences stress concentration; flaw size and orientation determine the effect on nominal stress. Each of these characteristics should be identified for each discontinuity detected, and the resulting information compared to the acceptance standard.

The examination of the finished radiograph should be made under conditions that favor the best visibility of detail - an area with subdued lighting to minimize distracing reflections from the viewing surface.

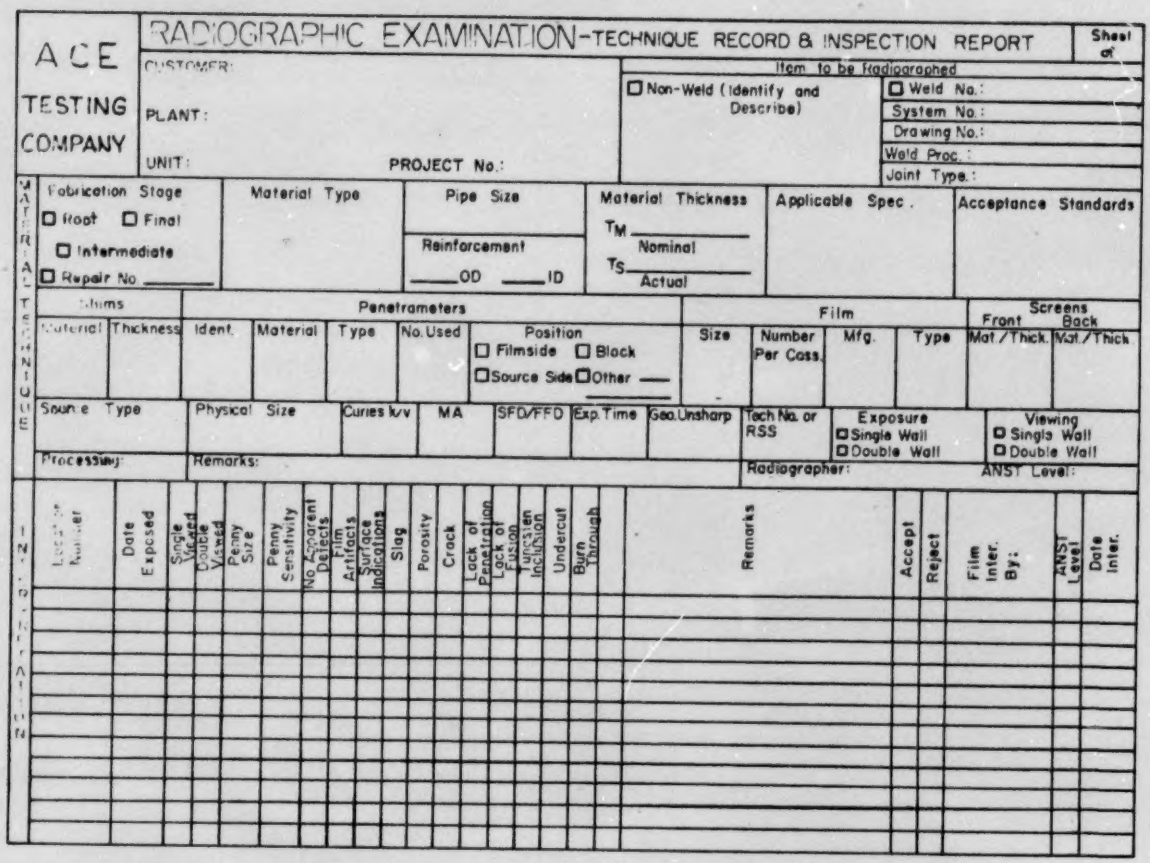
Most radiographic interpretation is conducted on film, viewed as negative images. An illuminator must be used to provide light of an intensity that will illuminate the areas of interest in the radiograph and be diffused evenly over the entire viewing area. For viewing industrial radiographs of moderate density (up to a value of about 2.0), an illuminator incorporating several fluorescent tubes is adequate. For high density films, however, a high-intensity illuminator must be used. This type provides variable controlled light which allows viewing of densities of 4.0 or even higher.

To see the finest detail in a radiograph, the illuminator should be masked to eliminate the glare of bright light at the edges of the film or transmitted through areas of low density. Some illuminators are equipped with adjustable diaphragm-type masks or metal-slide masks, but sheets of thin cardboard or opaque paper can be used as effectively to shield unwanted light from the observer.

## PROCEDURES AND REPORTS

For most industrial radiography applications and particularly in critical industries where operations can effect the health and safety of the general public, such as nuclear power plants, examinations must be conducted in accordance with written procedures. Procedures are developed by the user or the testing agency and cover all aspects of the work.

When the specimen is radiographed, all appropriate information about radiographic technique should be recorded on a technique record form such as that shown in Figure 26-7-8. The form shown is a dual-purpose form, e.g., for recording material technique information and film interpre-



ACE TESTING COMPANY

RADIOGRAPHIC EXAMINATION-TECHNIQUE RECORD & INSPECTION REPORT

Sheet of

CUSTOMER:

PLANT:

UNIT: PROJECT No.:

Item to be Radiographed

☐ Non-Weld (Identify and Describe)

☐ Weld No.:

System No.:

Drawing No.:

Weld Proc.:

Joint Type.:

MATERIAL TECHNIQUE

| Fabrication Stage | Material Type | Pipe Size | Material Thickness | Applicable Spec. | Acceptance Standards |
|---|---|---|---|---|---|
| ☐ Root ☐ Final ☐ Intermediate ☐ Repair No. ____ | | Reinforcement ____OD ____ID | $T_M$ ____ Nominal $T_S$ ____ Actual | | |

| Films | | Penetrameters | | | | | Film | | | | Screens | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Material | Thickness | Ident. | Material | Type | No. Used | Position ☐ Filmside ☐ Black ☐ Source Side ☐ Other ____ | Size | Number Per Cass. | Mfg. | Type | Front Mat./Thick. | Back Mat./Thick. |
| | | | | | | | | | | | | |

| Source Type | Physical Size | Curies k/v | MA | SFD/FFD | Exp. Time | Geo. Unsharp | Tech No. or RSS | Exposure ☐ Single Wall ☐ Double Wall | Viewing ☐ Single Wall ☐ Double Wall |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

Processing: Remarks: Radiographer: ANST Level:

INTERPRETATION

| Location Number | Date Exposed | Single Wall | Double Wall | Viewed | Penny Size | Penny Sensitivity | No Apparent Defects | Film Artifacts | Surface Indications | Slag | Porosity | Crack | Lack of Penetration | Lack of Fusion | Tungsten Inclusion | Undercut | Burn Through | Remarks | Accept | Reject | Film Inter. By: | ANST Level | Date Inter. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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Figure 26-7-8 Radiographic Examination Report Form

tation information and results. The technique information is necessary for the interpreter so that it may be determined if the radiographic technique was adequate prior to actual discontinuity interpretation and reporting. As a minimum, the technique information should include:

- X-ray-source energy (tube voltage) or type of radioisotope
- Tube current in milliamperes, or radioisotope-source strength in curies
- Focal-spot size of x-ray source or physical size of radioisotope source
- Exposure time
- Type of film (brand identification)
- Source-to-film distance
- Type and thickness of screens
- Description of filters, masks and diaphragms
- Viewing direction and method of marking
- Description and location of penetrameters
- Description (sketch) and major dimensions of test piece

A sketch of the shooting arrangement can be drawn on the back of the form, or on an attached sheet.

When the film is read and evaluated by the interpreter, the following information should be recorded on the report:

- Film Identification
- Date Exposed
- Double or Single Film Viewing
- Penetrameter Size and Sensivity
- Evaluation of Film Artifacts, if present
- Identification of Discontinuities, such as:
  (1) Surface Indications
  (2) Slag
  (3) Porosity
  (4) Inclusions

(5) Crack
(6) Lack of Penetration
(7) Undercut
(8) Burn-Through

- Disposition (Accept/Reject)
- Interpreters Name, Qualification Level, Date

The disposition of the examination results is usually very important, and specimen accept or reject decisions should be reported immediately. In many instances, delays in forwarding examination reports can cause costly delays in subsequent operations, whether they be in manufacturing, construction, maintenance or repair work.

## EXERCISES

1. Explain why a discontinuity is not necessarily a rejectable defect.
2. Briefly discuss how a crack can be caused in a material.
3. Are gas holes always open to the surface? Explain.
4. Why is it desirable to visually inspect a part even if it is going to be radiographed?
5. Can inadequate or rapid cooling of a weld metal result in a slag entrapment? Explain.
6. How would the lack of penetration in a weld appear in a radiograph?
7. Do propagating discontinuities usually render a part unacceptable?

8. How does excess metal in areas of the surface of a specimen appear on a radiograph?
9. Briefly discuss the characteristics of a discontinuity.
10. What can the radiographic film reader use as a basis of comparison to determine the acceptability of a specimen?
11. Discuss the necessary condition(s) required for viewing high density films successfully.
12. For each of the welds shown in the procedures section of this module evaluate the weld to the appropriate ASME porosity chart and table, and if not acceptable, state the reason for the rejection.
13. For each of the radiographs of pipe welds described in the procedures section, evaluate each weld to the requirements of USAS Appendix B (B 31.7), stating the reason for rejection if the weld isn't acceptable.
14. Obtain samples of both acceptable and rejected pipe welds and castings with radiographs of each and apply the appropriate ASME, ASTM, and USAS acceptance standards to evaluate if each of the parts is acceptable.

## MATERIALS


1. ASME Boiler and Pressure Vessel Code ANSI/ASME Volume V, Article 2, Radiographic Examination.
2. American Society for Testing and Materials, Recommended Practice for Radiographic Testing (E 94)
3. USAS Code for Pressure Piping Appendix B (B 31.7) "Nuclear Power Piping."

4. Samples of acceptable and rejected piping welds and radiographs of each.
5. Samples of acceptable and rejected castings and radiographs of each.

## PROCEDURES

1. For each of the following welds shown below, evaluate to the appropriate ASME porosity chart and table, and, if not acceptable, state the reason for rejection.

2. For each of the radiographs of piping welds described below, evaluate to the requirements of USAS B31.7, stating the reason for rejection if not acceptable.

Specimen 1

Material: 4" carbon steel pipe, 3/8" wall thickness

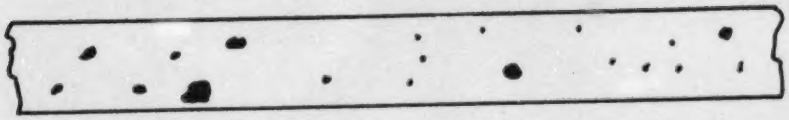
Indications: (a) 1/2" zone of incomplete fusion
(b) slag inclusion approximately 3/16" long
(c) no cracks or porosity

Accept _____

Reject _____

Reason _____

SPECIMEN 1



Material t = 3/8"

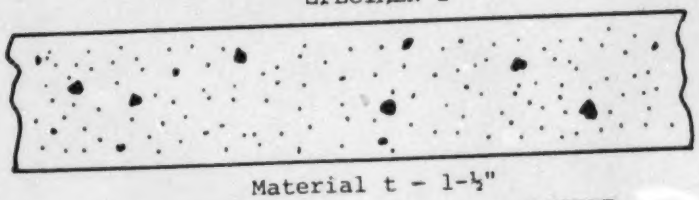
ACCEPT _____

REJECT _____

REASON _____

_____

SPECIMEN 2



Material t - 1-½"

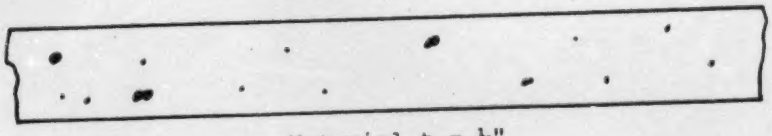
ACCEPT _____

REJECT _____

REASON _____

_____

SPECIMEN 3



Material t = ¼"

ACCEPT _____

REJECT _____

REASON _____

_____

Specimen 2

Material: 2" stainless steel pipe 1/4" wall thickness

Indications: (a) small surface cracks in cover pass
(b) no porosity
(c) tungsten inclusion, 1/8" long

Accept _____

Reject _____

Reason _____

Specimen 3

Material: 6" stainless steel pipe, 1/2" wall thickness

Indication: (a) small amount of porosity (acceptable to ASME Section III, Appendix IV)
(b) group of tungsten inclusions 7/16: long in aggregate length of 6", each less less than 1/16" long
(c) one elongated inclusion, length 3/16", not in line

Accept _____

Reject _____

Reason _____

3. Using the appropriate standards as given in the Materials section of this module, examine the piping welds and their associated radiographs to evaluate those which are acceptable or unacceptable.

4. Using the required standards, examine the samples of castings and their associated radiographs as listed in the Materials section of this module to determine which are acceptable.

## DATA TABLE

None.

## REFERENCE MATERIALS


Eastman Kodak Company. Radiography in Modern Industry, 1969

McGonnagle, Warren J., Nondestructive Testing, New York: McGraw Hill Book Company

Metals Handbook, Volume 11, Nondestructive Inspection and Quality Control, American Society of Metals

McMaster, Robert C. (ed.), Nondestructive Testing Handbook, New York: The Ronald Press Company

Omerman, Ralph T., Basic Concepts of Nuclear Chemistry, New York: Reinhold Publishing Corporation

ASME Boiler and Pressure Vessel Code an American National Standard ANSI/ASME BPV-V, Article 2 Radiographic Examination

American Society for Testing and Materials (ASTM), Recommended Practice for Radiographic Testing (E 94)

USAS Code for Pressure Piping, Appendix B, "Nuclear Power Piping"

# TEST

Answer the following statements as either true or false:

1. All discontinuities are rejectable defects. _____
2. Cracks are caused by stress perpendicular to the plane of the crack. _____
3. "Hot tears" are considered cracks. _____
4. Gas holes are always open to the surface. _____
5. Porosity is a form of gas holes or inclusions. _____
6. Visual examination of a part is unnecessary when the part is to be radiographed. _____
7. Tungsten inclusions are commonly found in castings. _____
8. Inadequate heat or rapid cooling of weld metal may result in slag entrapment. _____
9. Weld slag inclusions appear as light, uniformly rounded spots in radiographs. _____
10. Lack of penetration in a weld usually appears as a straight, dark line in the radiograph. _____
11. Tungsten particles from electrodes in the welding process usually melt and blend into the weld metal. _____
12. Gas holes and porosity are common discontinuities found in castings. _____
13. Excess metal in areas of the surface of a specimen appears as light areas on the radiograph thereof. _____
14. Propagating discontinuities usually render a part unacceptable. _____
15. Unfused chaplets occur only in weld fusion zones. _____

Complete the following statements:

16. Three of the distinguishing characteristics of a discontinuity are _____, _____ and _____.
17. Radiographic _____ are used by the film reader or interpreter as a basis of comparison to determine the _____ of the specimen.
18. Adequate _____ must be provided in order to view the areas of interest in a radiograph.
19. _____ lighting should be provided in the area where film viewing is performed.
20. High density films can be viewed successfully only with _____ illuminators.